OCT 6, 2021

Computational Needs for Clean Energy Transition

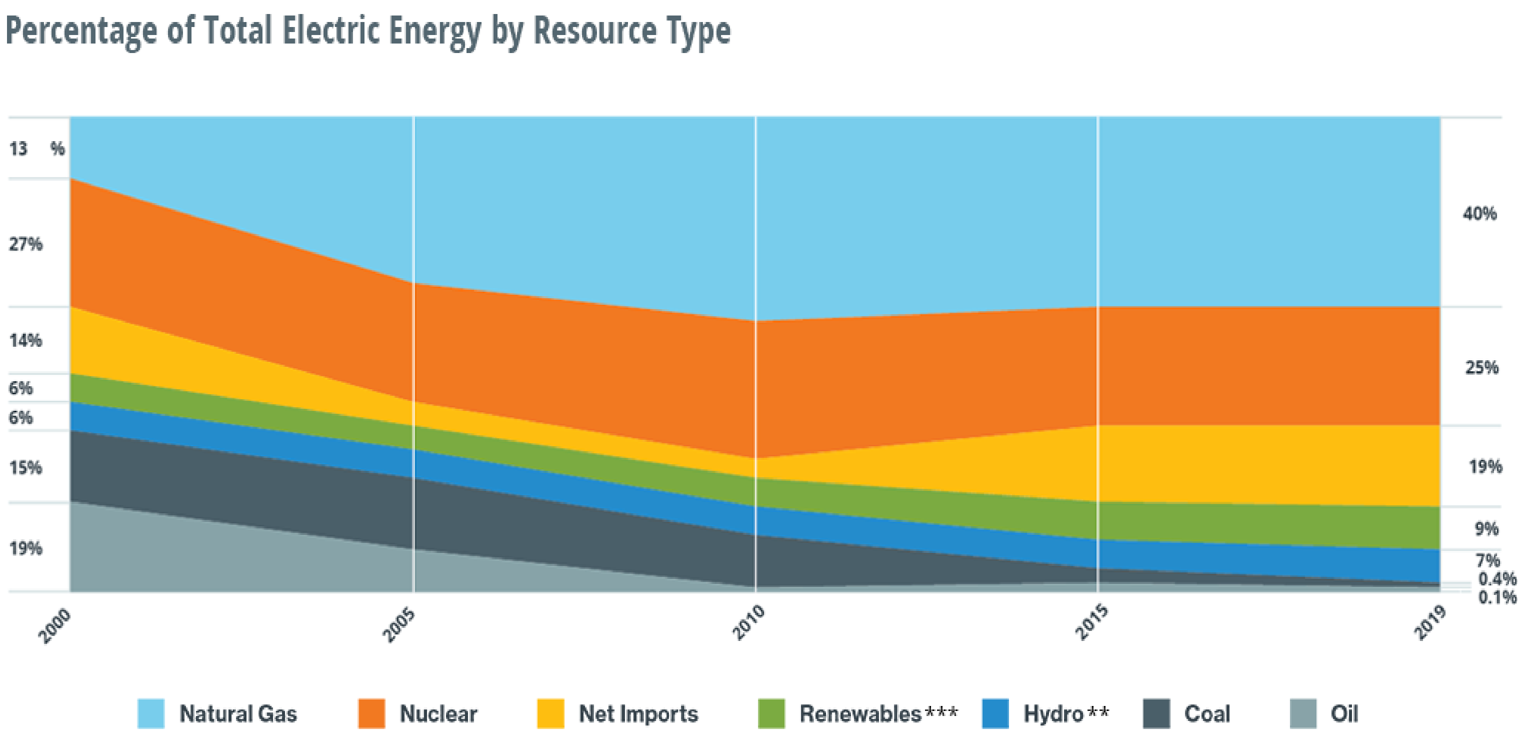
ARPA-E GO Competition Challenge 3 mini-Workshop

Tongxin Zheng

DIRECTOR, ADVANCED TECHNOLOGY SOLUTIONS

ISO NEW ENGLAND, INC.

Evolving Resource Mix in ISO NE Region



*Data are subject to adjustments. This chart approximates the amount of generation by individual fuels used by dual-fuel units, such as natural-gas-fired generators that can switch to run on oil and vice versa. Before 2016, generation from such units was attributed only to the primary fuel type registered for the unit.

**Includes pondage, run-of-river, and pumped storage.

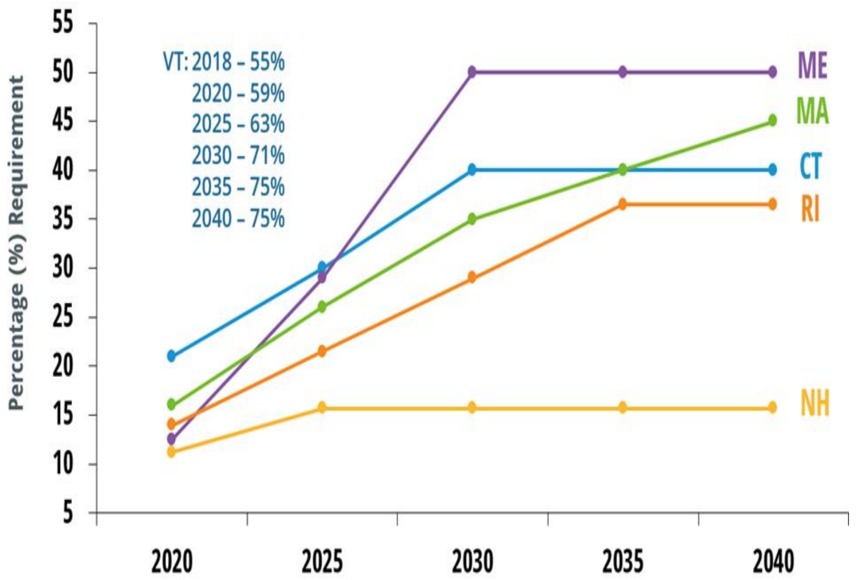
***Renewables include landfill gas, biomass, other biomass gas, wind, grid-scale solar, municipal solid waste, and miscellaneous fuels. Hydro is not included in this category primarily because the various sources that make up hydroelectric generation (i.e., conventional hydroelectric, run-of-river, pumped storage) are not universally defined as renewable in the six New England states.

Source: ISO New England

Decarbonization is changing the landscape of the grid

- Supply
  - Renewables (on-shore and off-shore wind)
  - Storage Resources
  - Distributed Energy Resources (behind-meter solar)
- Demand
  - Energy Efficiency
  - Electrification of transportation and heating sectors

State Renewable Portfolio Standard (RPS)



Notes: State RPS requirements promote the development of renewable energy resources by requiring electricity providers (electric distribution companies and competitive suppliers) to serve a minimum percentage of their retail load using renewable energy. Connecticut's Class I RPS requirement plateaus at 40% in 2030. Maine's Class I/IA RPS requirement increases to 50% in 2030 and remains at that level each year thereafter. Massachusetts' Class I RPS requirement increases by 2% each year between 2020 and 2030, reverting back to 1% each year thereafter, with no stated expiration date. New Hampshire's percentages include the requirements for both Class I and Class II resources (Class II resources are new solar technologies beginning operation after January 1, 2006). New Hampshire's Class I and Class II RPS requirements plateau at 15.7% in 2025. Rhode Island's requirement for 'new' renewable energy plateaus at 36.5% in 2035. Vermont's 'total renewable energy' requirement plateaus at 75% in 2032; it recognizes all forms of new and existing renewable energy and is unique in classifying large-scale hydropower as renewable.

Source: ISO New England

Increased Level of Uncertainty

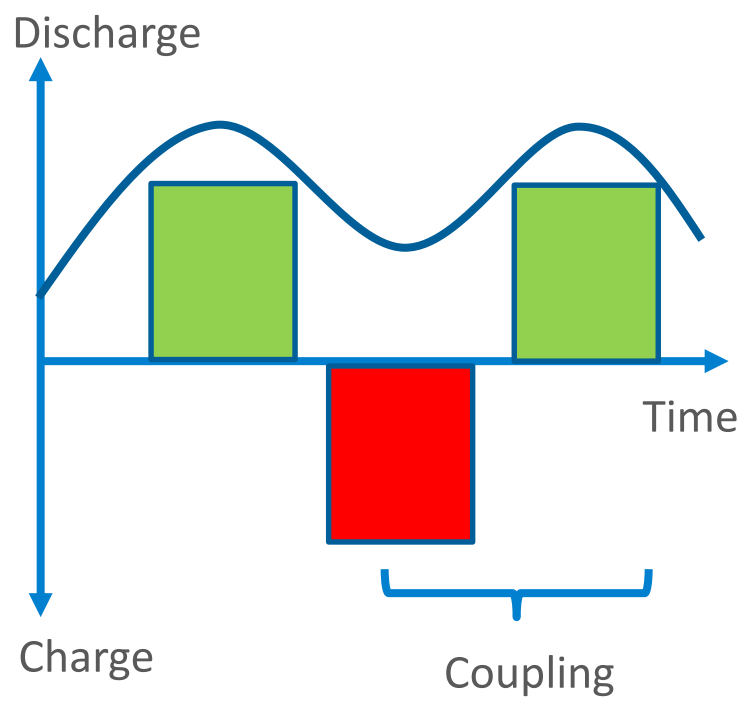
- Wind and solar generation output are weather dependent.
- Load forecasting accuracy has been declining in the past few years, before the introduction of Day-ahead solar forecasting in the ISO NE region.
  - Long-term and Real-time load forecasting remain challenging
- Fluctuation of the renewable generation increases the system operational risk.

Complex Grid Operation

- Significant amount of solar PV are behind the meter and are not dispatched by the transmission system operator.
- DERs are often not observable, and their impact on the transmission operation may be non-predictable.
- Controlling massive number of DERs at the ISO level is far too complicated and inefficient.

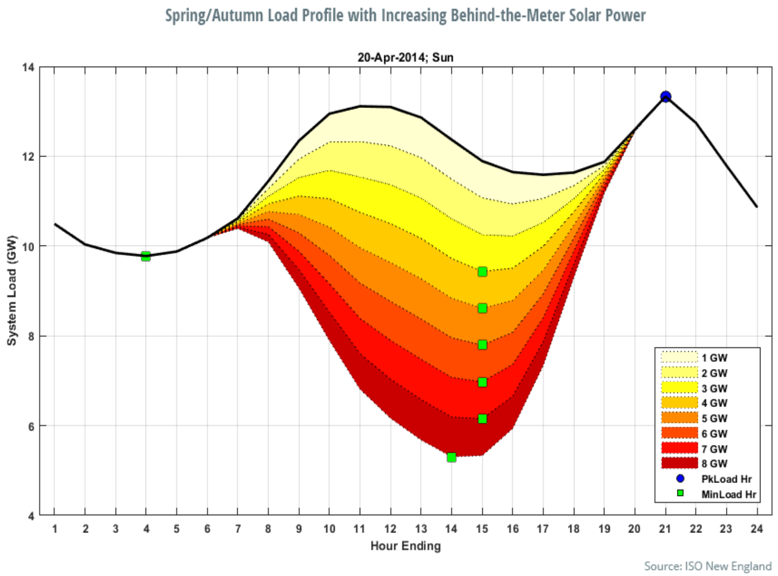
Tightened Market Coupling

- Efficient operation of Storage resources depends on the information of multiple market intervals.
- The charge and discharge cycle needs to be determined simultaneously.
- Ramping and fuel storage limitation make market coupling more profound.



Dramatic Shift in Load Pattern

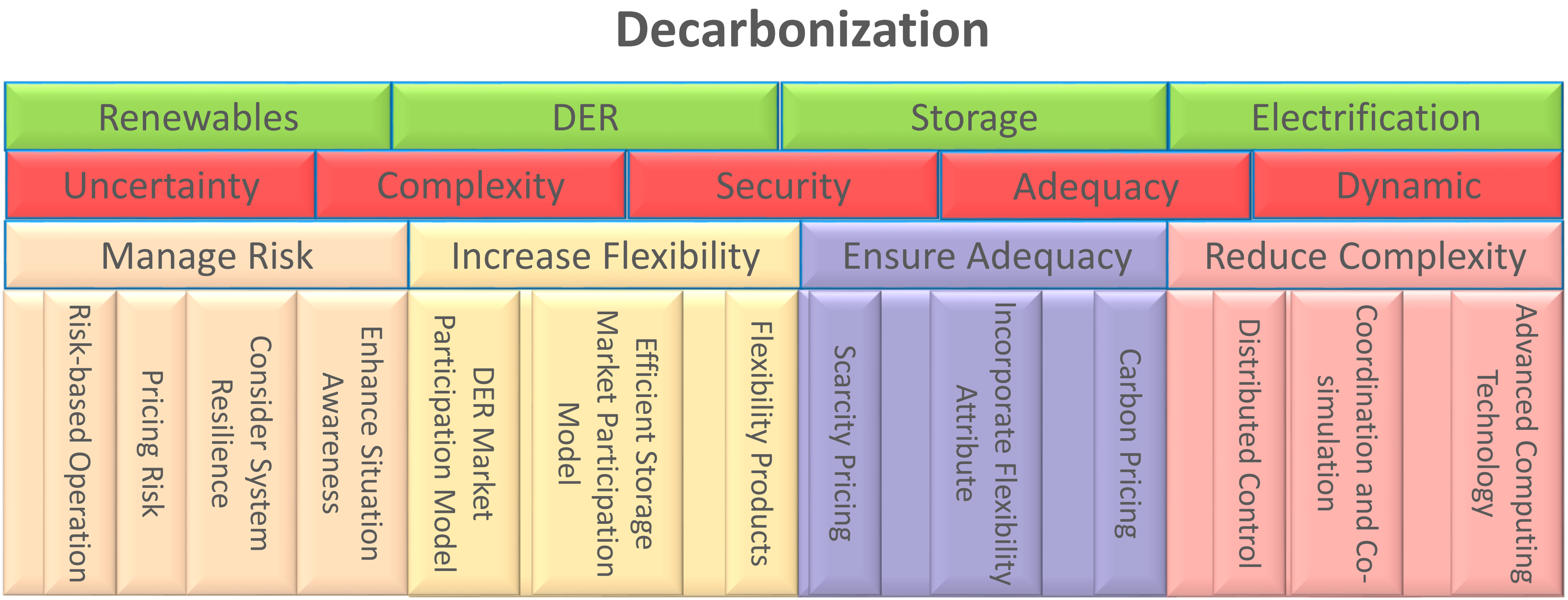
- Solar integration reshapes the load curve
- Electrification of transportation and heating sectors introduces new customer behavior.
- Capability to responds to theses changes is needed.



Energy Security under Extreme Weather Events

- Constraints in the fuel supply system can significantly impact the grid operation.
- Winter operation in New England can be challenging under extended cold snap.
  - Heating demand depletes natural gas, leaving no gas for gas generators from pipeline
  - LNG availability is not guaranteed
  - Oil tank refill are often delayed due to the dangerous road conditions
  - Cold temperature and snow coverage often reduce solar generation significantly
  - Cold weather also makes the off-shore wind unavailable

Future Needs



Operational Risk Management

- Power system operation is basically a risk-management process.
  - Balancing supply and demand
- Current security standards for system operation such as N-1 are often deterministic
  - Limited to a small set of events and silent on the renewable generation
  - Failed to consider the event probability
  - Do not consider the event impact
  - No consideration of cost vs. reliability benefit
- *Risk-based approach should strike a better balance between cost and reliability*

Manage Power System Uncertainty

- Preventive actions <– risk avoidance
  - Unit Commitment
  - Generator Dispatch
  - Demand Response Dispatch
  - Voltage Control
  - Transmission Limit Enforcement (static and dynamic security)
  - Maintaining Ancillary Service Requirements
  - Line Switching
- Corrective actions <– risk mitigation
  - Load Frequency Control
  - Corrective Generator Dispatch
  - Load Switching and Shedding
  - Voltage Reduction
  - External Transaction Curtailment
  - Emergency Energy Purchase from Neighboring Control Area
  - Line Switching
- *Incorporating corrective actions requires significant computational efforts*

Extreme Event Modeling and System Resilience

- Extreme events create significant stress to the system operation
  - Low probability and high impact
  - Man-made or natural disaster
  - Affecting multiple systems
- Transmission system resilience
  - Cascading failures
  - Dispatch with resilience constraints
- Supply system resilience
  - Introducing market products to ensure fuel procurement
  - Multi-day-ahead markets for better utilization of fuel
- *Extreme events should be considered in critical decision making processes.*

Outage Scheduling

- The goal of outage scheduling is to arrange power system equipment maintenance in an economic fashion without causing reliability problem.
- Current practice contains separate processes for
  - Generation maintenance scheduling
    - Market participants (MP) submit generator maintenance schedule.
    - ISO performs capacity analysis for maintenance period.
    - ISO coordinates with MPs to reposition outage schedules when reliability issues raise.
  - Transmission outage scheduling
    - Market participants submit transmission maintenance schedule.
    - ISO performs reliability studies (power flow analysis) for the maintenance period based on the peak load condition.
    - ISO performs economic studies (production cost simulation) to evaluate the congestion impact of the transmission outage schedule.
    - ISO coordinates with MPs to reposition outage schedules when either reliability or economic issues raise.

Outage Scheduling - Issues

- Issues with current practice
  - Loose coordination between generation and transmission outage scheduling
  - No economic studies for the generation outage scheduling
  - Capacity analysis does not consider transmission security
  - Capacity analysis is performed based on selected peak load conditions
  - Outage repositioning is based on a first-come first-serve scheme, which fails to recognize the underlying economics
  - Economic analysis only considers one future scenario, which ignores uncertainties in many parameters such as
    - Load forecast
    - Interchange flow
    - Generator’s forced outage
    - System topology

Outage Scheduling – Future Needs

- A better outage scheduling process is needed to
  - Coordinate both generation and transmission outage schedules
  - Optimize the outage windows
  - Consider system uncertainties
  - Respect the system reliability criterion
- Such an outage scheduling problem in general is
  - a stochastic programming problem with integer variables and chance constraints
  - computationally challenging
  - in need of fast and robust solution algorithms

Energy Security Assessment

- Current practice of energy security assessment
  - Provide an energy security forecast for the region by considering
    - Energy inventory
      - Oil, Storage state of charge
    - Gas pipeline system conditions
    - LNG availability
  - The analysis is performed on expected system conditions
    - Hard to justify the accuracy of the assessment
- Future needs of energy security assessment
  - Probabilistic assessment
  - Consideration of extreme events
  - High computational efforts

Ensuring System Adequacy

- System planning is a very complex process, and involves
  - Resource Adequacy Planning
    - Looks into several years ahead
    - Ensures the system has enough capacity
    - Considers the load and generator uncertainties
    - Often ignores the detailed transmission network
    - Adheres to the one-in-ten planning criterion
  - Transmission Planning
    - Identifies the transmission bottleneck
    - Considers detailed AC transmission network
    - Performs power flow and contingency analysis based on future worst case scenario of the system
    - Conducts system stability study

Needs in Capacity Market

- Forward Capacity Market (FCM) procures generation capacity
  - through an auction process
  - Considers trade-off between cost and reliability using simplified capacity demand curves
  - with consideration of only zonal transmission limitation
- Some issues with FCM
  - Loose coupling between transmission and generation planning
  - Does not consider
    - The dynamics of a resource' contribution to reliability
    - Operational flexibility needs
    - Energy security attribute
    - Resource's environmental attribute
    - Extreme system conditions
    - Transmission network limitation
    - Transmission investment
    - Non-transmission alternatives
- *A combined transmission and generation adequacy market with consideration of above limitations creates a very challenging problem to solve.*

Questions